

Occurrence, Physiologic Effects, and Toxicity of Heavy Metals—Arsenic, Cadmium, Lead, Mercury, and Zinc—in Marine Biota: An Annotated Literature Collection

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Introduction

The impact of industrial progress on the concentrations of metals in seawater, marine biota, and marine sediments is most graphic when tragedies such as occurred in Minamata, Japan, are brought to light. Apparent dangers, unfortunately, are not confined to inshore fishing areas. In May 1971, a study conducted by the U. S. Food and Drug Administration indicated that approximately 5% of swordfish available to retailers contained mercury at or above the FDA guideline of 0.5 ppm. Nearly all swordfish food products were recalled as a result.

Some of the routes of entry for metals into the oceans have been slowed or stopped in recent years, but too little voluntary or enforced regulation has been implemented. Municipal wastes, industrial discharges, surface runoff, spillage and weathering of vessel protective agents, ocean dumping, and aerial inputs account for most ocean metal pollution. Weathering accounts for almost one-half the yearly input of mercury into our environment. Release of metal-rich sediments from ocean beds into the hydrosphere occurs at rates dependent on the interaction of physical phenomena regulating current and upswelling.

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Occurrence of Metals in Marine Biota

The metals emphasized in this literature collection—arsenic, cadmium, lead, mercury, and zinc—are ubiquitous in our environment. In general, ash content of aquatic organisms tends to reflect the elemental composition of their microenvironment. Marine seaweed, *Fucus vesiculosus*, is a faithful indicator species. The marine sediment-living protozoan, *Cristigera* spp., is so sensitive to the toxic effects of lead, mercury, and zinc as to be suggested as a toxicity indicator species.

Mechanisms for active regulation of zinc and arsenic levels have been reported; the mechanism which regulates zinc in *Tapes* can effectively adapt to higher ambient levels which are toxic to nonadapted animals. In dogfish shark, exclusion processes maintain fetal mercury levels far below those in maternal blood. While mercury was not excluded from the fetus in Canadian seals, neither did it accumulate there as has been reported in humans. In Northern fur seals, mercury is readily transferred from maternal blood to the fetus and from maternal blood to milk to the newborn.

Distribution of the various metals within an organism is species specific. Highest mercury levels are found in the liver of seal, shark, and porpoise, the kidney in marine fish, and the gill in crab; cadmium in the hepato-pancreas and the gill of crab; lead in the brain of sea lion; and zinc in

the stomach of mussel and the liver in Thornback Ray. In phytoplankton, uptake and elimination of zinc is influenced by illumination, pH, and temperature. In crab, mercury and cadmium uptake are affected by salinity and temperature; cadmium distribution in crab is influenced by temperature. Low salinity results in decreased sensitivity.

Mercury and other metals are concentrated and accumulated along the food chain. Levels of mercury attained in large marine fish (tuna, marlin, salmon) have been attributed to these processes. Accumulation studies in sea trout, salmon, seals, and harbor porpoises show definite correlations between age and mercury levels.

Toxicity

Toxicity is the one characteristic that the metals arsenic, cadmium, lead, mercury, and zinc all have in common; each is capable of causing death and at lower doses can inhibit the development and growth of young marine animals. The relative toxicities of these five metals vary among species, though mercury is usually seen to be the most toxic and arsenic, the least. Growth in marine phytoplankton and other marine algae is totally inhibited when sufficient concentrations of mercury are present.

Together, metals typically act synergistically to potentiate toxicity. In oyster, elevated zinc levels decreased the rate of cadmium uptake. Zinc and cadmium levels in an organism are usually inversely related.

Literature Survey

Literature specifically related to metal pollution in the marine environment and its effects on marine organisms accounts for only a small portion of the data collected on metal pollution in aquatic environments. We recently began building this computerized data base on the metals arsenic, cadmium, lead, mercury, and zinc in relation to marine biota. These 128 records each consist of author(s), title, journal, citation, our abstract of the report, and key terms. Author, key term, and permuted title indexes allow easy entry into the record file. The listing is arranged alphabetically by author. The number of papers relating to each metal categorized by year are listed in Table 1.

Annotations from original papers reflect author's remarks and conclusions. Our computerized collection will be updated on a routine basis with periodic publication and dissemination.

Table 1. Number of papers by metal.

Year	As	Cd	Hg	Pb	Zn
1924-1960	2	1	5	1	3
1963-1969	1	3	2	4	20
1970	—	2	5	1	4
1971	—	5	9	5	5
1972	4	4	19	4	10
1973	10	21	17	13	15
1974	3	2	7	2	2
Totals	20	38	64	30	59

For this report the computerized collection includes references only up to early 1974.

Papers received too late for computer input are listed in references.

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